Bridge Asset Model

A Bridge Model is defined as a set of tools or methods to maximize the benefit for the available budget for bridges including the calculation of Remaining Service Life (RSL), and the Deterioration Models for the bridges. The Remaining Service Life (RSL) gives an indication of the number of years of serviceable life the structure has remaining before it has reached a "serviceability failure state". The Deterioration Models consist of series of deterioration curves for Deck, Substructure, and Superstructure.

The Calculation of Remaining Service Life

Remaining Service Life (RSL) gives an indication of the number of years of serviceable life the structure has remaining before it has reached a "serviceability failure state". Currently within the UDOT system, a failed state is reached whenever any of the primary NBI Condition Indexes (Deck, Superstructure, or Substructure) reaches an index value of 3 out of a possible maximum index value of 9.

At present, a series of look up tables are used to estimate the remaining service life based on existing rates of deterioration**.** Table 1 outlines the remaining service life for various levels of condition.

Index Range	Culvert	Deck	Superstructure	Substrucrture
8.5 - 9.0	76	50	70	56
8.0 - 8.5	69	47	64	52
7.5 - 8.0	60	44	57	48
7.0 - 7.5	49	40	48	42
6.5 - 7.0	40	34	40	36
6.0 - 6.5	32	27	31	28
5.5 - 6.0	26	20	25	21
5.0 - 5.5	21	15	19	16
4.5 - 5.0	17	11	15	12
4.0 - 4.5	14	7	10	8
3.5 - 4.0	10	5	7	5
3.0 - 3.5	7	3	3	2
2.5 - 3.0	5	1	0	0
2.0 - 2.5	2	0	0	0
1.5 - 2.0	0	0	0	0
1.0 - 1.5	0	0	0	0
0.5 - 1.0	0	0	0	0
0.0 - 0.5	0	0	0	0

Table 1: RSL Values for Index Ranges

Deterioration Models

The following deterioration models have been implemented within dTIMS CT. The Table 2 outlines the performance curve equations that have been implemented within dTIMS CT for analysis and the table is followed by a series of figures (Figure 1 and Figure 2) outlining the deterioration curves in graphical format.

Deterioration Model Name	Description	Expression
ancCND_STR_CULVERT	Calculate Culvert Condition	IF (STRUCTURES->CULVRATING < 0.0, 0.0, 9.0 – 13.59140915* EXP(-(60.0/ nAAV_AGE_CULVERT)* *1.942)))
ancCND_STR_DECK	Structure Deck Alpine	MIN (9.0, 9.0-13.59140915* EXP(-((45.0/ nAAV_AGE_DECK) * * 1.153)))
ancCND_STR_SUBSTRUCTURE	Substructure	IF (STRUCTURE->MAINSPANS <= 1.0, 9.0 – 13.59140915* EXP (-((75.0/ nAAV_AGE_SUB) * * 2.462)), 9.0 – 13.59140915*EXP (-((75.0/ nAAV_AGE_SUB) * * 1.742)))
ancCND_STR_SUFF_RATE	Structure Sufficiency Rating	100.0 – 135.9140915*EXP(-((75.0/ nAAV_AGE_SUFF) * *1.4514))
ancCND_STR_SUP_CNT_COMPLX	Superstructure Condition for Prestressed Continuous Concrete - Complex	9.0 – 13.59140915*EXP(-((75.0/nAAV_ AGE_SUP) ** 2.462))
ancCND_STR_SUP_CNT_SIMPLE	Superstructure Condition for Prestressed Continuous Concrete - Simple	9.0 – 13.59140915*EXP(-((75.0/nAAV_ AGE_SUP) ** 2.893))
ancCND_STR_SUP_CONCRETE	Superstructure Condition for Concrete	9.0 – 13.59140915*EXP(-((75.0/nAAV_ AGE_SUP) ** 2.893))
ancCND_STR_SUP_STEEL	Superstructure Condition for Steel	9.0 – 13.59140915*EXP(-((75.0/nAAV_ AGE_SUP) ** 3.527))
ancCND_STR_SUP_TIMBER	Superstructure Condition for Timber	9.0 – 13.59140915*EXP(-((75.0/nAAV_ AGE_SUP) ** 1.984))

Table 2: Deterioration Models

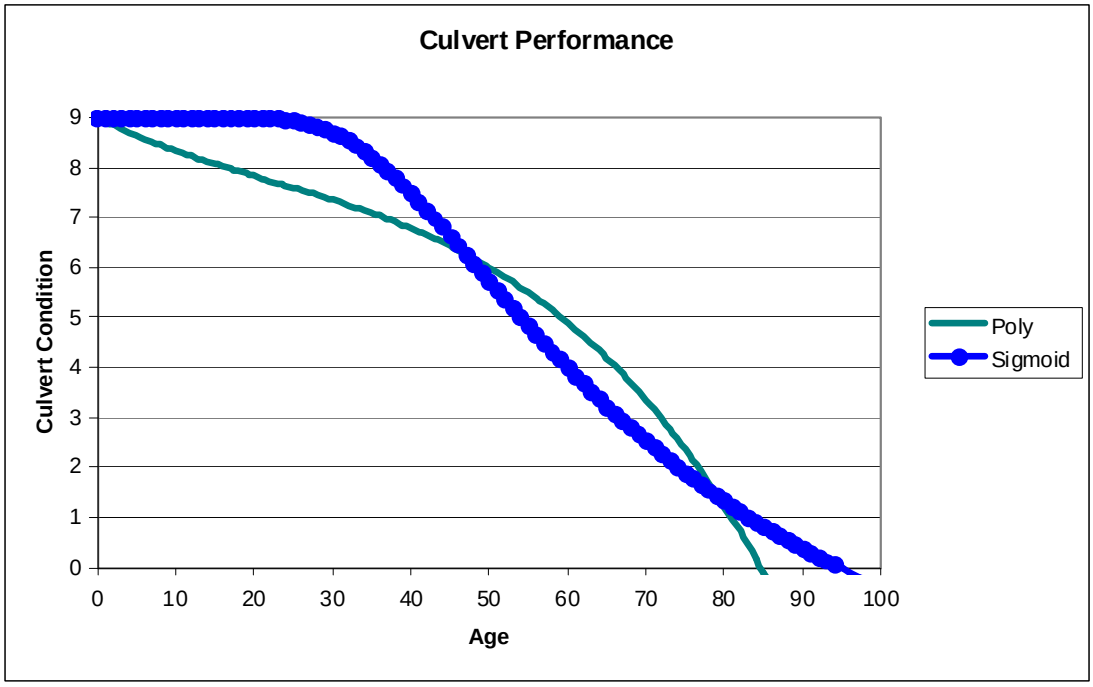

Figure 1: Culvert Deterioration Models

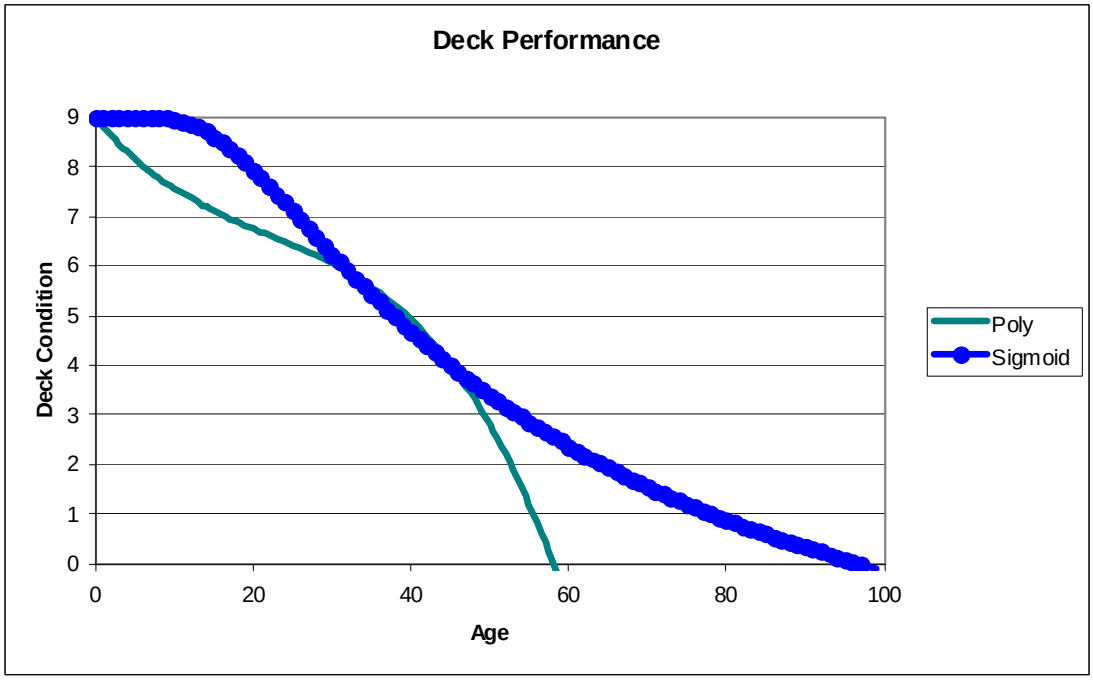

Figure 2: Deck, Sub, and Superstructure Deterioration Models

A sigmoid or traditional “S” shaped curve allows for a time of little or no deterioration at the start of the assets life and then two additional periods of deterioration through a specified failure point.

Treatment and Triggers

Within the lifecycle cost analysis performed by dTIMS CT, dTIMS CT uses treatments to slow down the deterioration of the infrastructure, to correct minor deterioration, to rehabilitate moderate amounts of deterioration, and to replace infrastructure that has deteriorated to the point where repair and rehabilitation are no longer cost effective. Within dTIMS, the following treatments have been implemented:

CULVERT_REHAB

A culvert rehabilitation treatment is the same as a concrete repair treatment but accounts for more extensive damage and deterioration.
Treatment is triggered when:
Culver Condition >= 4 And Culvert Condition <= 5
Treatment cost is calculated as:
$250,000 * 1.75 multiplier and adjusted for inflation

CULVERT_REPLACE

A culvert replacement treatment involves replacing the entire culvert with a new box or pipe using prefabricated components.
Treatment is triggered when:
Culver Condition <= 4 And Sufficiency Rating <= 55.0
Treatment cost is calculated as:
$750,000 * 2.00 multiplier and adjusted for inflation

DECK_MINOR_REHAB

The deck repair treatment includes repairing minor cracks and spalls, repairs to the joints and sealing the deck surface with polymer or asphalt overlay.
Treatment is triggered when:
Deck Condition >= 5 And Deck Condition <= 6
Treatment cost is calculated as:
Deck Area * $25.00 * 1.50 multiplier and adjusted for inflation

DECK_REPLACEMENT

The deck replacement treatment includes replacing the deck using prefabricated and accelerated bridge construction practices.
Treatment is triggered when:
Deck Condition <= 4 or Superstructure Condition <= 4
Treatment cost is calculated as:
Deck Area * $85.00 * 2.00 multiplier and adjusted for inflation

SUPERSTRUCTURE_PAINT

The preventive maintenance treatment on Superstructure includes sealing concrete girders and repairing minor paint defects and topcoat steel girders.
Treatment is triggered when:

Superstructure Condition >= 5 And <=6 And Sufficiency Rating >= 55.0

Treatment cost is calculated as:

Deck Area * $20.00 * 1.50 multiplier and adjusted for inflation

SUPERSTRUCTURE_MINOR_REHAB

The superstructure rehabilitate treatment includes repairing cracks and spalls to the bridge components straightening and repairing steel and concrete from collision damage, repairing pins, hangers and other components as well as a replacement of the paint system and strengthening girders as necessary.
Treatment is triggered when:

Superstructure Condition >= 5 And Superstructure Condition <= 6

Treatment cost is calculated as:

Deck Area * $45.00 * 1.75 multiplier and adjusted for inflation

STRUCTURE_REPLACEMENT

The replace structure treatment replaces the entire structure using prefabricated and accelerated bridge practices.

Treatment is triggered when:

Condition values <= 4 or sufficiency <= 55.

Treatment cost is calculated as:

Deck Area * $300.00 * 2.00 multiplier and adjusted for inflation

dTIMS CT Strategies

During the LCCA Analysis, dTIMS CT generates several maintenance and rehabilitation strategies for each structure included within the analysis. A typical strategy consists of one or more treatments being carried out on the structure over the analysis period:

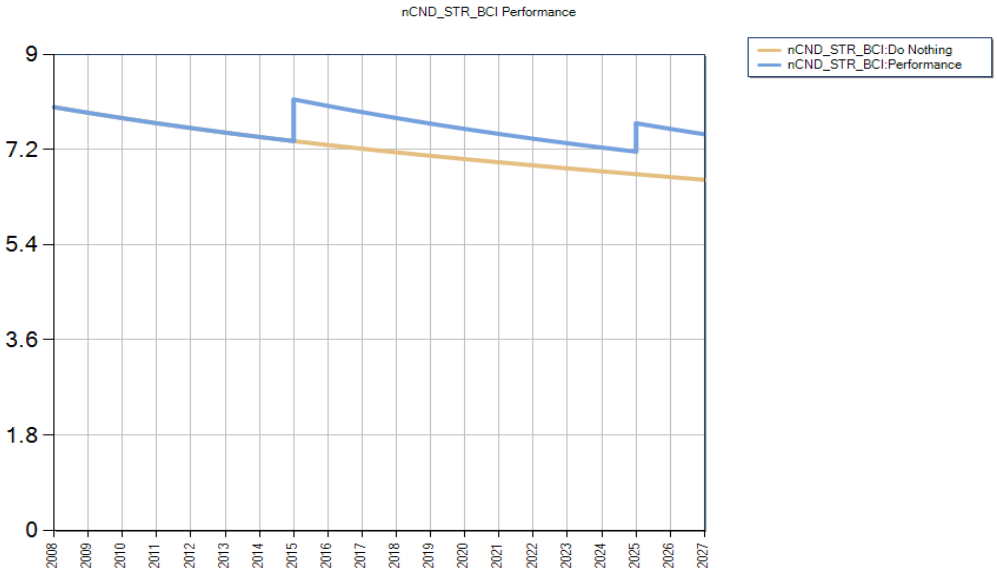

Figure 3: Typical Strategy Performance

Figure 3 outlines a typical strategy generated for a structure in the dTIMS CT LCCA. The strategy includes an initial treatment (in this case preventive maintenance in 2017) and a subsequent treatment later on in the analysis (in this case a repair in 2025).

Another example of a typical strategy is shown in Figure 4:

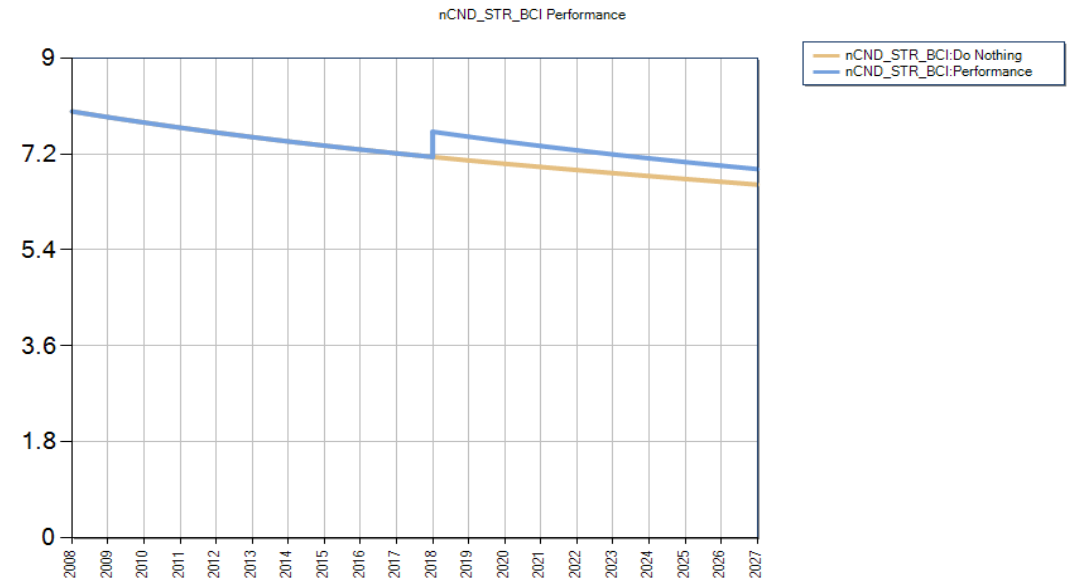

Figure 4: Typical Strategy Performance

Figure 4 shows another typical strategy for the same structure as used in Figure 3, except this strategy only has 1 treatment generated, which is a repair to the deck only in 2018.

During the analysis, dTIMS CT generated 92 different alternative strategies for the structure shown in Figure 3 and Figure 4 which, when plotted in terms of the strategies benefits and costs, look as follows (Figure 5):

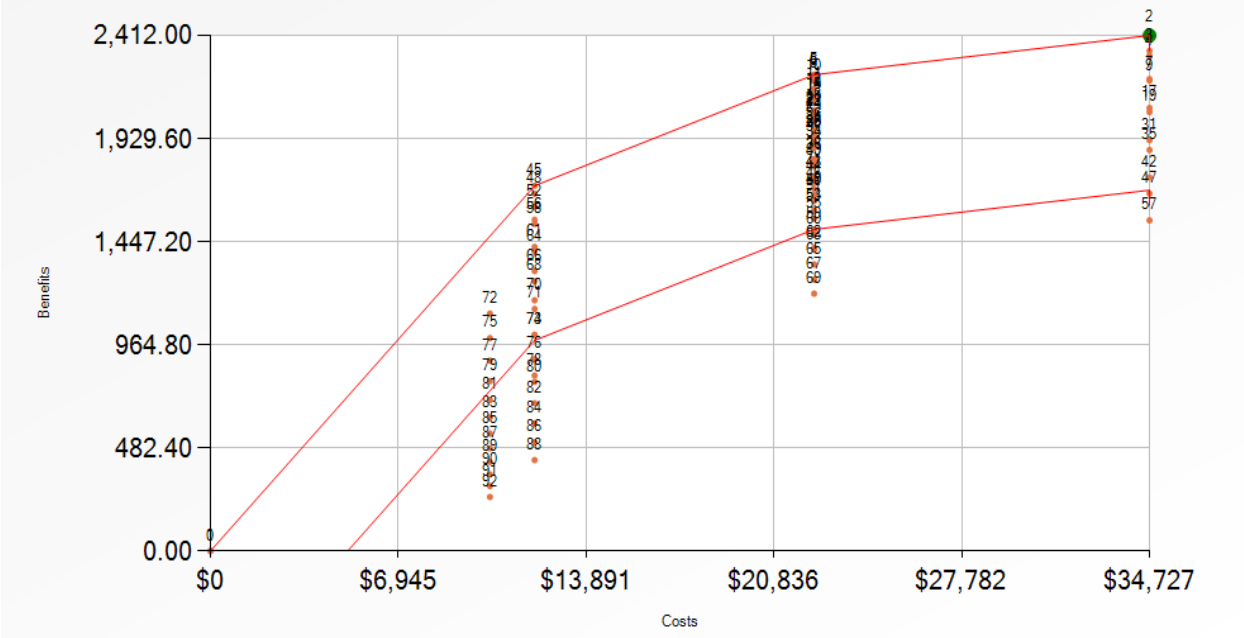

Figure 5: Efficiency Frontier

During optimization, dTIMS CT evaluates the benefits and costs of the alternative strategies generated for each structure included in the network and attempts to maximize the benefit for the available budget. Higher budget dollars may enable dTIMS to recommend multiple treatments in multiple years (Figure 3) while optimizing smaller budget amounts may result in dTIMS CT recommending only 1 treatment on a structure (Figure 4).

Analysis Results

When the analysis is finished, the user can access several charts and graphs that detail the resulting performance of the strategies for many different what if scenarios. The following Condition Distribution graph is based on a Budget Scenario that starts with 53 million dollars in the first year and then approximately $30 million dollars in the following years (increasing at 3% per annum).

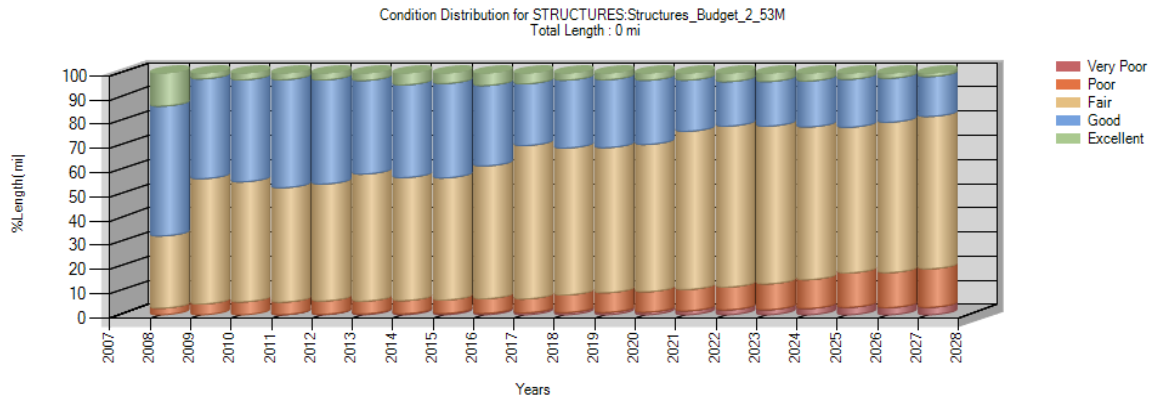

Figure 6: Condition Distribution

The user can also compare the results of different scenarios on network performance using an Average Condition graph. The following Average Condition graph displays the average condition for several different Budget Scenarios:

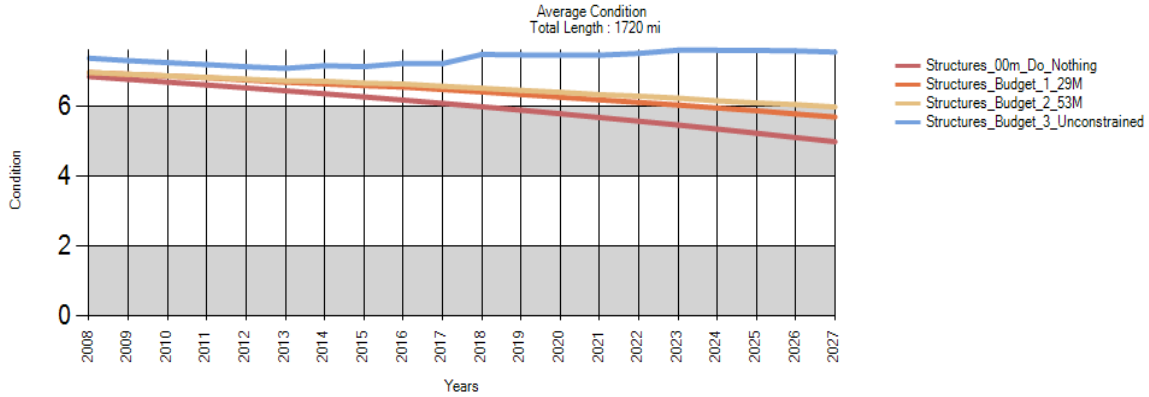

Figure 7: Average Network Condition

Construction Program

For each budget scenario that is analyzed in dTIMS CT a construction program is produced based on maximizing the condition of the bridges over the length of the analysis period. The construction program indicates the maintenance, rehabilitation and replacement work that is recommended based on the analysis parameters and the available budget.